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WATER ABSORPTION AND THERMAL PROPERTIES OF PMMA REINFORCED BY NATURAL FIBERS FOR DENTURE APPLICATIONS

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ABSTRACT

The water absorption and thermal conductivity of denture base materials are important properties due to effect on dimensional stability and sensory of food during mastication. This paper discusses the effect of two natural fibers (siwak and bamboo) which used as reinforcement for properties (water absorption and thermal conductivity) of PMMA. The two kinds of fibers used in three different lengths (2, 6 and 12mm) and three concentrations (3, 6 and 9 wt. %). The results showed that the percent water absorption, thermal conductivity and thermal diffusivity increased with increase fiber length and weight fraction. The highest values of water absorption for bamboo specimens and siwak specimens (6.21 % and 7.21 % respectively) at (9wt.%) and (12mm) fiber length. The maximum values of thermal conductivity and thermal diffusivity for bamboo specimens (0.2216 W/m^{0}K and 0.1628 mm^2/sec), while for siwak specimens (0.2408 W/m^{0}K and0.1747mm^2/sec), respectively at optimum condition of (9wt. %) and (12mm) fiber length.

KEYWORDS: Thermal Properties, Water Absorption, Natural Fibers, PMMA & Denture

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Original Article

INTRODUCTION

Recently natural fibers have attracted the care of researcher and scientists due to the benefits of these fibers over conventional synthetic fibers. These natural fibers are cheap, light weight, high specific properties, available, biodegradable and non-abrasive, different from other fibers. On the other hand, there are certain disadvantages of these fibers such as incompatiblewith the matrix (polymer), and poor resistance to moisture to the highest degree decrease the potential of natural fibers to be utilized as reinforcement in matrix [1]. The bonding between the natural fiber and the matrix (polymer) can be increased by altering the fiber surface. Chemical treatment enhances the adhesion by removing the organic residue from a surface of the fiber and those, enable an interlocking mechanism with the matrix [2].

R. K. Durkan [3] estimate the effect of the different dental fiber system on heat and microwave polymerized denture base resins. The results show that the value of water absorption of denture base polymers is higher when the specimens are reinforced with the fiber systems. X. Zhang [4] studied the effect of Salinized aluminum borate whiskers (ABWs) on PMMA properties (flexural strength, surface hardness, and thermal stability) by varying the content of (ABWs) from 1 to 20 wt.%. The result showed that the (ABWs) improve the properties of PMMA and 5% provided the highest reinforcement. Hanan Abdul et. al [5] determined the influence of adding siwak micro powder on the certain mechanical properties of acrylic resin. The results showed that the addition of (7 %) siwak powder to the acrylic resin revealed a

significant decrease in compressive strength, impact strength and tensile strength.

Intisar J. Ismail et. al [6] studied the effect of Alumina (Al_2O_3) Nano particles in three different percentages (1, 2, 3 wt %) on some properties of heat cured poly methyl meth acrylate denture base material. The results showed that the transverse strength increases with the addition of (1 & 2wt %) Al_2O_3 to heat cured PMMA denture base material and reduces with the addition of 3%. In addition, a considerable improvement in surface hardness and non-significant differences in roughness were noticed for each fraction.

S. I. Salih et al [7] study the effect of water absorption on compressive strength of PMMA by adding different sorts of Nano powder (fly ash, fly dust, zirconia and aluminum) at three different VOL% to PMMA. The results show that the compression strength values with and without the effect of water absorption, improved by the addition of Nano powders.

Hanan Abdul-Rahman K. [8] studied the effect of 2% mixture of salinized polypropylene and siwak fibers with 4 mm length on physical and mechanical properties (transverse strength, shore D hardness, shear bond strength, thermal conductivity, surface roughness, Water sorption) of heat cure resin denture base. The result showed that addition of salinized mixture of siwak and polypropylene fibers into heat cure PMMA improve the tested physical and mechanical properties.

Based on the literature survey, many of these studies dealt with the effect of different fibers and particles with the properties of PMMA. But, to our knowledge, never has been studying the effect of bamboo fibers and siwak fibers in the current fiber content and length on the properties of the polymer composites.

SPECIMENS PREPARATION ANDTESTS

Materials

The matrix material which is used in this study is self-curing base resin poly methyl methacrylate (PMMA) manufactured by (Spofa Dental) company. This type of material characterized by many properties compared to other kind of PMMA polymer. Figure (1) shows the methyl methacrylate powder and monomer that are used to fabricate composite specimens in this study.

Figure 1: The Methylmethacrylate Powder and Monomer

Reinforcing Fibers

Siwak and bamboo fibers used in this study. The two natural fibers are cut into three lengths and alkali treated to enhance adhesion with matrix with 5% (w/v) alkali (sodium hydroxide) solution at 25 °C for 24 h, maintaining a fiber-to-liquor ratio of 1:30 (w/v). Then The fibers washed several times with distilled water to remove excess alkali sticking on their surface, and neutralized (PH-7) with distilled water containing a few drops of acetic acid and finally washed with distilled water, then the treated fibers were dried at room temperature for 5 days and finally kept in hot air oven at (50-60 °C) until dry.

Figure 2: Sample of Siwak Fiber

Figure 3: Sample of Bamboo Fibers

Composite Specimens Preparation

According to the required selection ratio of weight fractions of the reinforcement material weighing the amount of reinforced material (siwak fibers and bamboo fibers) by using electronicbalance with accuracy (0.0001) digits depending on the total weight of the matrix material PMMA required for filling the mould cavities by using the theory of rule of mixture. The liquid monomer (MMA) with one type of treated fibers (Bamboo or siwak) should be mixed together at room temperature homogeneous and continuously, so it must be sure of homogeneity of the mixture, before added powder to it to produce composite materials. The powder then added to the mixture and gradually mixed (the acrylic base resin is mixed in the volumetric ratio 3:1 (three parts of powder: 1 part of liquid)).

The curing process of acrylic performed by placing the closed metallic mould inside the curing device at temperature equal to around (55 °C), and pressure equal to around (2.5 bar), the closed mould remained inside curing device for around (30 min) in order to complete polymerization process of acrylic specimens and to improve physical properties, the characteristic of this process is the residual monomer will be at minimum level and the polymerization process might be completed in short time.

The acrylic resin samples were de-molded to remove from the metallic mould cavities with very smooth upper and lower surface, followed by heat treatment at 55°C for 3 hour to remove residual stresses as a result of de-molding of the specimens from the metallic mold cavity.

Water Absorption Test

The water absorption test is achieved according to according to (ASTM D1037-98). In this test, the samples were immersed in distilled water at room temperature for (24hr), then samples removed from the distilled water and surface wiped off with the dry cloth and weighed by digital balance and water absorption

was obtained by using equation (1). Figure (4) shows the standard specimen and the composite specimens of this test[9]. The water absorption can be calculated according to the equation below.

$$\text{Water absorption percentage} = (W_s - W_d)/W_d \times 100 \qquad (1)$$

Where:

W_d: Mass of the specimen before immersion (dry).

W_s: Mass of the specimen after immersion for (24 hr in distilled water).

(a) (b)

Figure (4): (a) The Water Absorption Test
(b) The Composite Specimens

Thermal Properties Test

The thermal properties (thermal conductivity, thermal diffusivity, and specific heat capacity) are properties gained from the hot disk test for composite samples, at room temperature.

The composite samples were prepared according to (ISO-22007 standard) [10], as shows in Figure (5).

The relationship between these properties is shown by the equation (2) [11].

$$D_{th} = K / (C_p.\rho) \qquad (2)$$

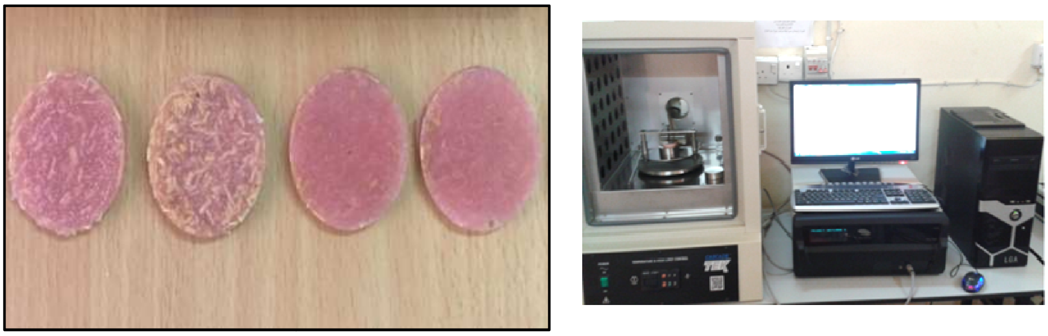
Where:

D_{th}: Thermal diffusivity (mm^2/s).

Cp:Specific heat (heat capacity) at constant pressure (MJ/ $m^{3o}K$).

K:Thermal conductivity (W/m.ºK).

ρ: Mass Density (Bulk Density) (kg/m^3).



(a) (b)

Figure (5): (a) The Thermal Properties Test Samples (b) Thermal Properties Test Instrument

EXPERIMENTAL RESULTS AND DISCUSSIONS

Water Absorption Results

The water absorption values of the pure PMMA, composite materials with (bamboo and siwak) for all samples that were fabricated in the current work are illustrated in figures (6 & 7).

It can be observed from figures that the water absorption increases with an increase in the weight fractions of (bamboo &siwak) fibers. This is due to the affinity of the fibers towards the moisture, and also may be due to a high moisture absorption level of natural fibers in polymer matrix that result from polar hydroxide groups in the fibers [12 & 13].

Figures, also show increase water absorption value with fiber length, and this increase is due to the inability of the matrix material to completely saturate the fiber at higher fiber length which likely facilitated moisture ingress [14].

In general specimens with siwak fibers have a higher rate of water absorption than specimen with bamboo fibers since the composite specimen with siwak fibers, have density lower than specimens with bamboo fibers. Density decrease with increase moisture absorption [14].

Pure PMMA specimen has the lower value of water absorption that equal (2.545 %), while the composite specimen with siwak and bamboo fibers have higher value that reach (7.206 %) and (6.212%), respectively at optimum condition of fiber weight (9%) and fiber length (12mm).

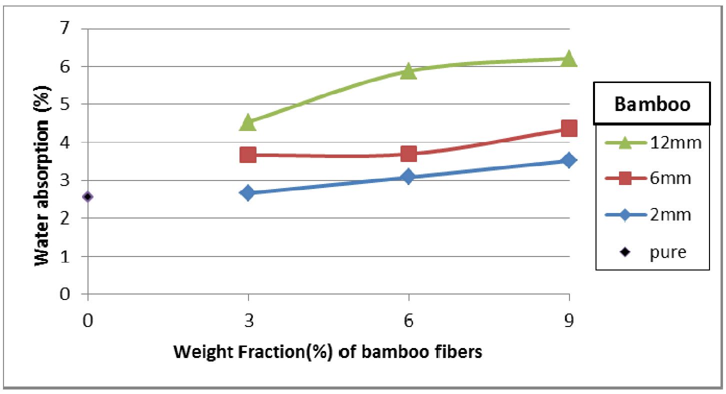


Figure 6: Water Absorption (%) of Composite Specimens with Weight Fraction of Bamboo Fibers

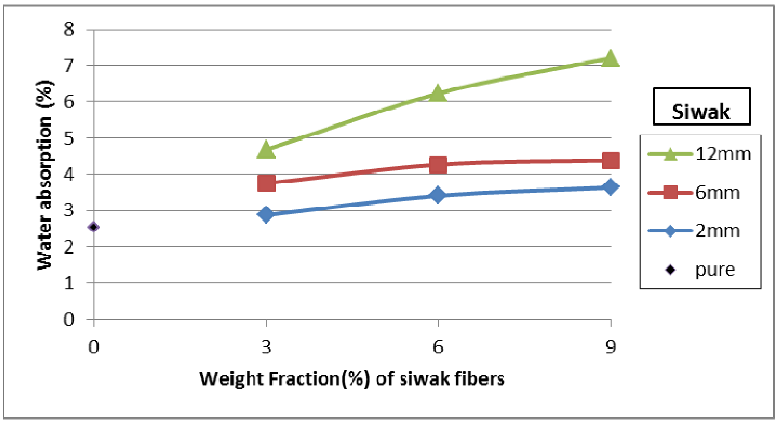


Figure 7: Water Absorption (%) of Composite Specimens with Weight Fraction of Siwak Fibers

Thermal Conductivity Results

Thermal conductivity of composite samples represents the movement in the molecular chains of polymer in composite specimens due to thermal energy at a rate proportional to the content of the conductive materials [15]. Thermal conductivity results are illustrated in figures (8 & 9).

Figures show pure PMMA has lower thermalconductivityvalue that equal (0.1618 W/m.°K),while the composite specimen has higher value than PMMA alone.

Also, increasing the weight fraction of both types of fibers increases the thermal conductivity of the composite specimen and this is due to that fibers have higher thermal conductivity than PMMA matrix. So, the presence of the short fibers can considerably improve the thermal conductivity [16].

From figures it can be observed the thermal conductivity of composite specimens changing with fiber length and reach maximum value at (12mm) fiber length.

The maximum value of thermal conductivity of composite specimens with (bamboo and siwak) fibers at optimum condition of fiber length (12mm) and weight fraction (9%) equal to (0.2216 W/m.°K) and (0.2408 W/m.°K), respectively.

Specimens with Bamboo fibers have lower thermal conductivity value than specimens with siwakfibers.

The percentage of increase in thermal conductivity for specimen reinforced by siwak fibers was (48.8%) compared with pure PMMA specimen, While for specimen reinforced with bamboo fibers was (36.9%) at optimum condition of fiber length (12mm) and weight fraction (9%).

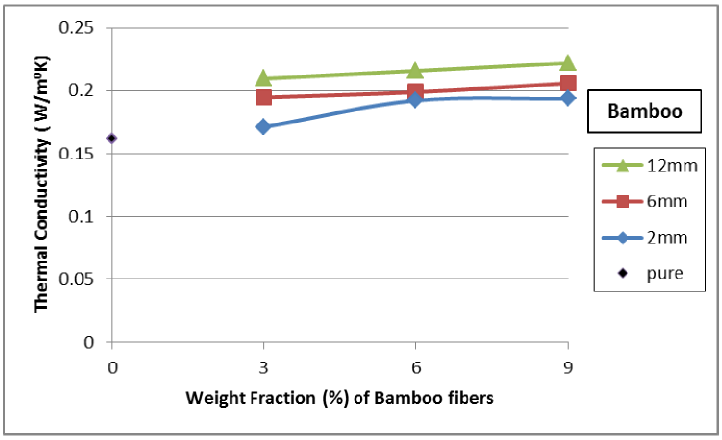


Figure 8: Thermal Conductivity of Composite Specimens with Bamboo Fibers

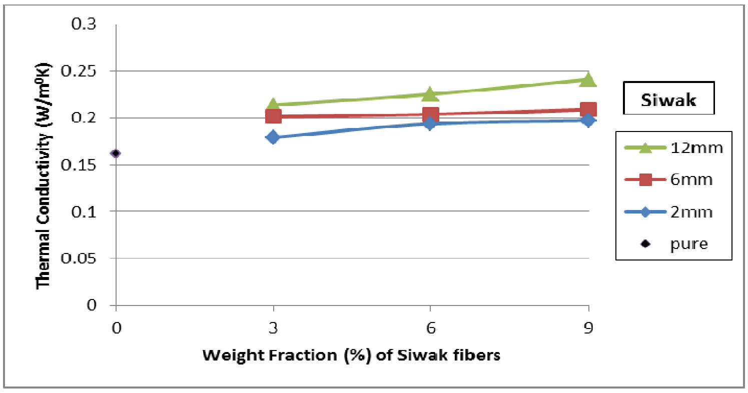


Figure 9: Thermal Conductivity of Composite Specimens with Siwak Fibers

Thermal Diffusivity Results

Thermal diffusivity of the samples indicates the change in temperature of composite specimens when heat applied [17].

Figures (10 & 11) show the thermal diffusivity of pure and composite specimens reinforced by bamboo fibers and siwak fibers, respectively.

Composite specimens have thermal diffusivity increased with increasing weight fractions and fiber length of fibers (bamboo & siwak),So the higher values of composite specimens reinforced by both types of fibers were observed in fiber length equal (12mm) and weight fraction equal (9%) and reach (0.1628 mm^2/sec) for composite specimens having bamboo fibers and (0.1747 mm^2/sec) for specimens having siwak fibers.

PMMA alone has a lower value of thermal diffusivity than composite specimen reach (0.06231 mm^2/sec). Siwak specimens have a higher value of thermal diffusivity than bamboo specimens.

The percentage of increase in thermal diffusivity for specimen reinforced by siwak fibers compared with pure PMMA specimen was (180%). While for specimen reinforced with bamboo fibers was (161%).

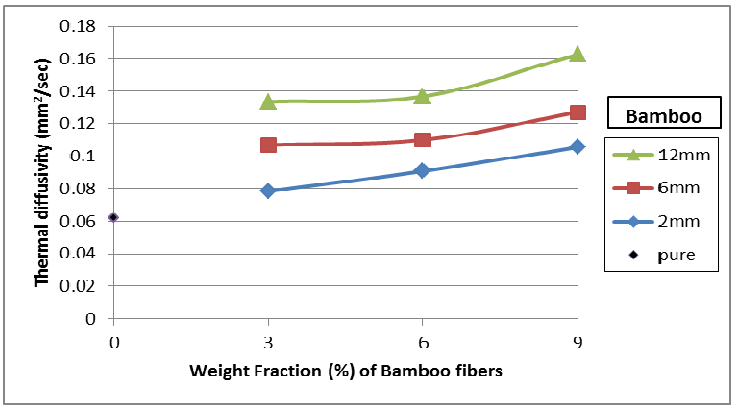


Figure 10: Thermal Diffusivity of Composite Specimens with Bamboo Fibers

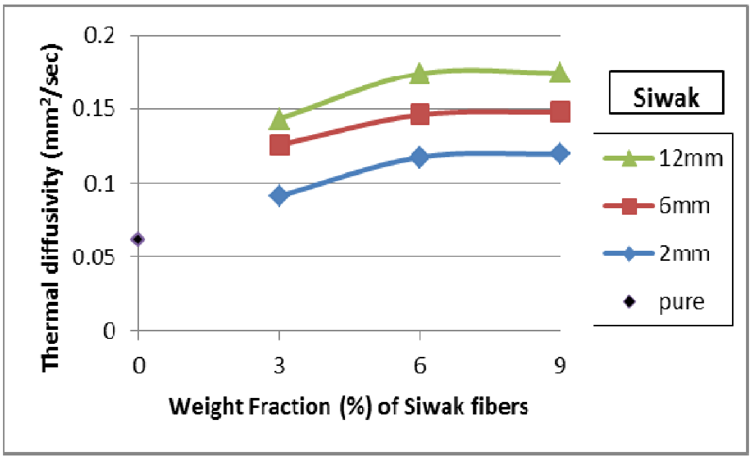


Figure 11: Thermal Diffusivity of Composite Specimens with Siwak Fibers

Specific Heat Results

Specific heat for composite specimens represent the energy needed to raise the temperature of composite by one degree [18].

Specific heat magnitudes could be increased with reduced weight fraction of fibers (bamboo & siwak) compared with the magnitude of PMMA alone as shown in figures (12 & 13).

The highest values of specific heat for composite specimen are obtained for composite with (12mm) fiber length that is due to the heat insulation ability of the fibers [19].

The pure PMMA has higher value than composite specimens with reinforcing fibers (bamboo and siwak) that equal (2.324 $MJ/m^3.K$).

The lower values of specific heat found with composite specimens at (9%) weight fraction and (2mm) fiber length and reach (1.263 $MJ/m^3.K$) for composite specimens with bamboo fibers and (1.226 $MJ/m^3.K$) for composite specimens with siwak fibers.

Composite specimens with Bamboo fibers have a higher value of specific heat than specimens with siwak fibers

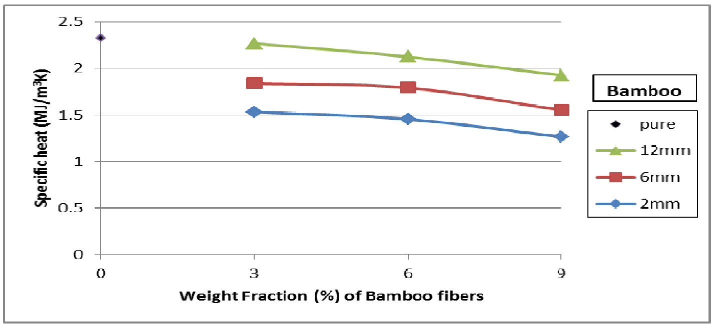


Figure 12: Specific Heat for Composite Specimens with Bamboo Fibers

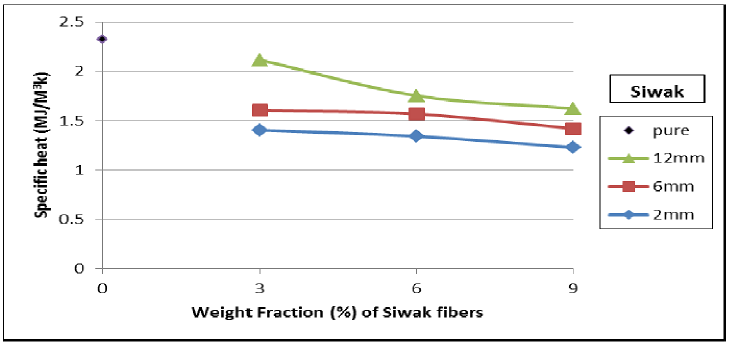


Figure 13: Specific Heat for Composite Specimens with Siwak Fibers

CONCLUSIONS

- The control specimen has the lowest value of water absorption (%) and equal to (2.545%).
- The water absorption (%) of the composite specimen increase as fiber weight fraction and fiber length increase of both fibers and the maximum values for siwak specimens equal to (7.21 %), while for bamboo specimens equal to (6.21 %), found in fiber weight fraction (9%) and (12mm) fiber length, respectively.
- The control specimen has the lowest value of the thermal conductivity and thermal diffusivity which reach (0.1618 W/m^{0}K and 0.06231 mm^2/sec) respectively.
- The thermal conductivity increase in weight fraction and fiber length of both types of fibers. The highest values of thermal conductivity obtained from composite specimens with siwak fibers and equal (0.2408 W/m^{0}K), while for bamboo specimen the value reaches (0.2216 W/m^{0}K) at optimum condition of (12mm) fiber length and (9 wt %).
- The thermal diffusivity increase in weight fraction and fiber length of both kinds of fibers. The highest values of thermal diffusivity obtained from composite specimens with siwak fibers and equal (0.1747 mm^2/sec) while for bamboo specimen the value reaches (0.1628 mm^2/sec) at optimum condition of (12mm) fiber length and (9 wt %).
- The specific heat decreases with weight fraction of the two fibers.

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